BTeV Ring Imaging Cherenkov Detector (WBS 1.3)

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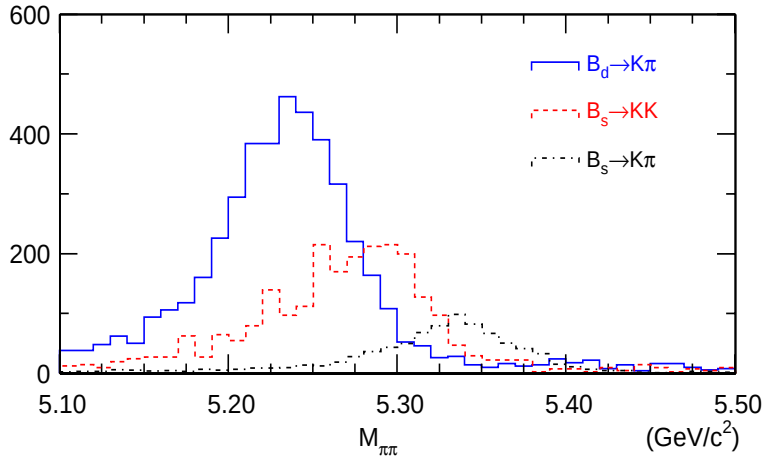
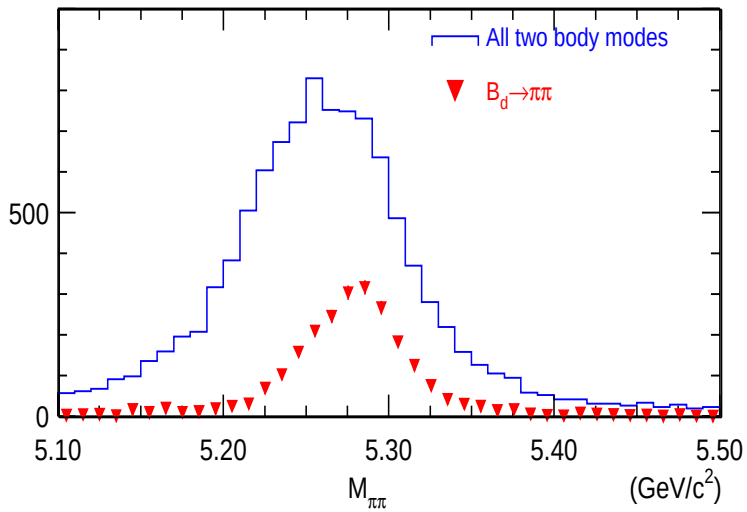
Outline

- Introduction and overview of the BTeV Ring Imaging Cherenkov Detector (RICH)
- WBS 1.3 – RICH
  - RICH Detector system
  - Project Management overview
- Presentations prepared for the breakout sessions

Introduction

- Charged particle identification is a key element of our experiment. The Ring Imaging Cherenkov Detector (RICH) has three main goals:
  - Distinguish π, K and p over most of the momentum range relevant for hadronic decays of the B_d,B_u and B_s mesons (3-70 GeV)
  - Maximize the impact of K tagging, by identifying π, K and p down to very low momentum (~3 GeV)
  - Extend the momentum and solid angle coverage where we can achieve excellent lepton ID (complementing the μ and e-cal detectors)

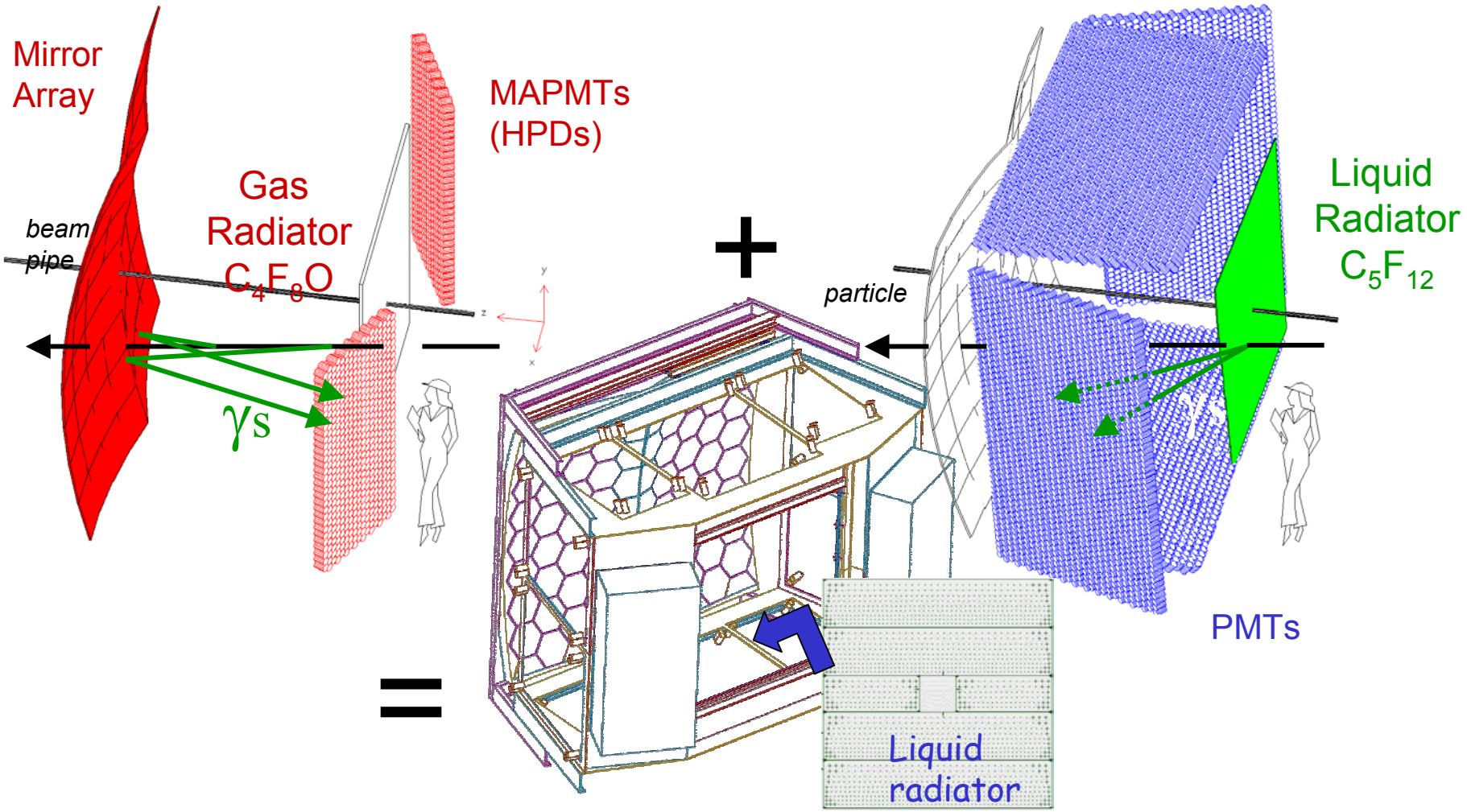




The BTeV RICH Components

Mirror Focused Gas Radiator RICH

Proximity Focused Liquid RadiatorRICH

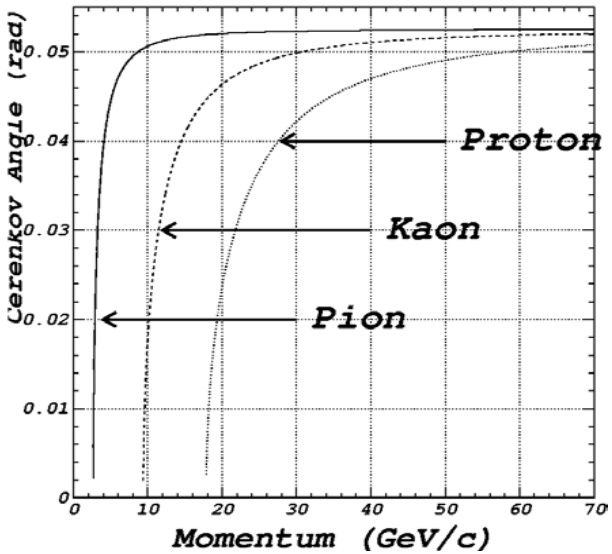


The BTeV RICH: a good match to our physics goals

Gas

C_4F_8O

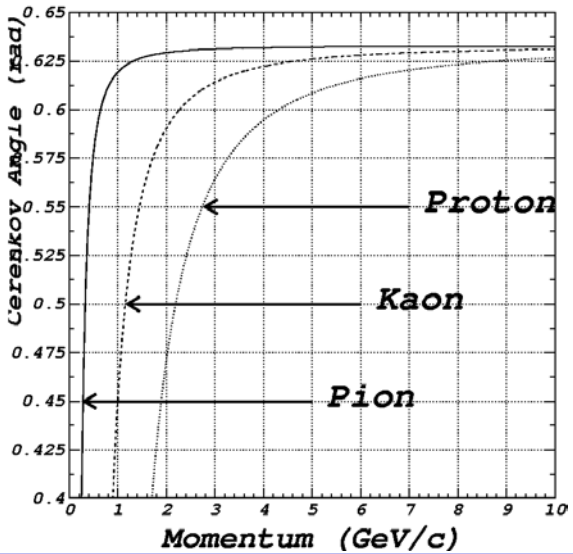
n=1.00138



Liquid

C_5F_{12}

n.1.29



- The combination of gas and liquid radiator RICH achieve the desired particle species separation over the whole momentum range of interest:
  - The gas radiator RICH provides good hadron separation up to 70 GeV/c
  - The liquid radiator RICH provides p/K separation below 9.5 Gev/c.
  - The RICH detector provides μ ID up to 17 GeV/c and electron ID up to 23 GeV/c over the full solid angle coverage of the BTeV tracking system.

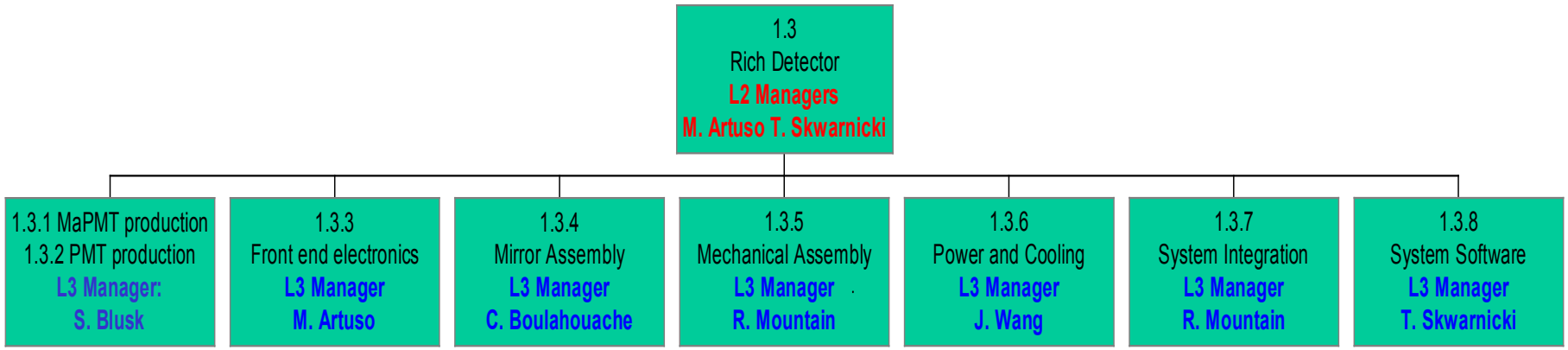
RICH Components WBS 1.3

- Photon detectors for GAS RICH
- Photon detectors for Liquid RICH
- Front end electronics
- Mirror
- Mechanical Assembly
- High-voltage, low-voltage and cooling
- System integration and tests prior to installation in the C0 collision hall
- Software (run control, slow control and monitoring, databases)

Base cost: $12.1M (Material: $9.9M, Labor: $2.3M)

+ NSF support for R&D work

Organization WBS 1.3



The RICH Detector Components

- The photon detectors for the GAS RICH
  - Baseline is 16 channel Hamamatsu MAPMTs with DEP 163 channel HPDs as viable alternative
- The photon detectors for the LIQUID RICH
  - 3" PMTs (off-shelf products of Hamamatsu, Burle, Photonics and ElectronTubes)
- The front end electronics
  - Front end hybrids developed in collaboration with IDEAS, NO and front end multiplexer boards developed at Syracuse University
- The mirror
  - Light-weight mirror made up of multiple tiles, CMA, Tucson, AZ baseline solution, several alternative options
- The mechanical structure (a superstructure where all the various components are assembled in a staged installation)
- High voltage, low voltage and cooling infrastructure (1KV HV+ low noise ±5V system).

Gas RICH Photon Detector

System	HPD	MAPMT
Number of tubes	944	9016
Cost per tube	$6353	$529
Photodetector cost	5,997 k$	4,769 k$

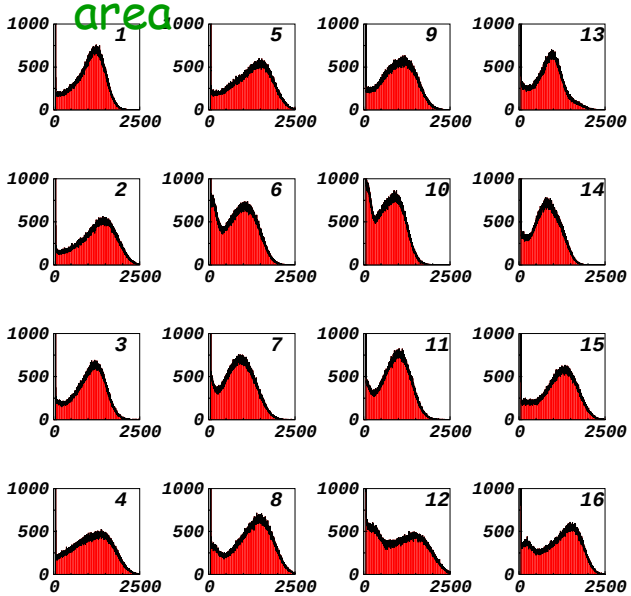
System	HPD	MAPMT
Effective pixel size	5.5 mm hex	6 mm square
N_γ σ_{track}	50.3 0.118 mr	52.0 0.115 mr
HV	-20kV and -19.9kV and -15.8kV and -0.05 kV	-0.9 kV
Current draw	no	yes
Gain	5×10^3	10^6
Magnetic field sensitivity	Large, but OK shielded	R8900 – OK shielded

- Both systems satisfy our physics requirements
- Cost and system issues favor the MAPMTs →MAPMTs are our baseline photon detector

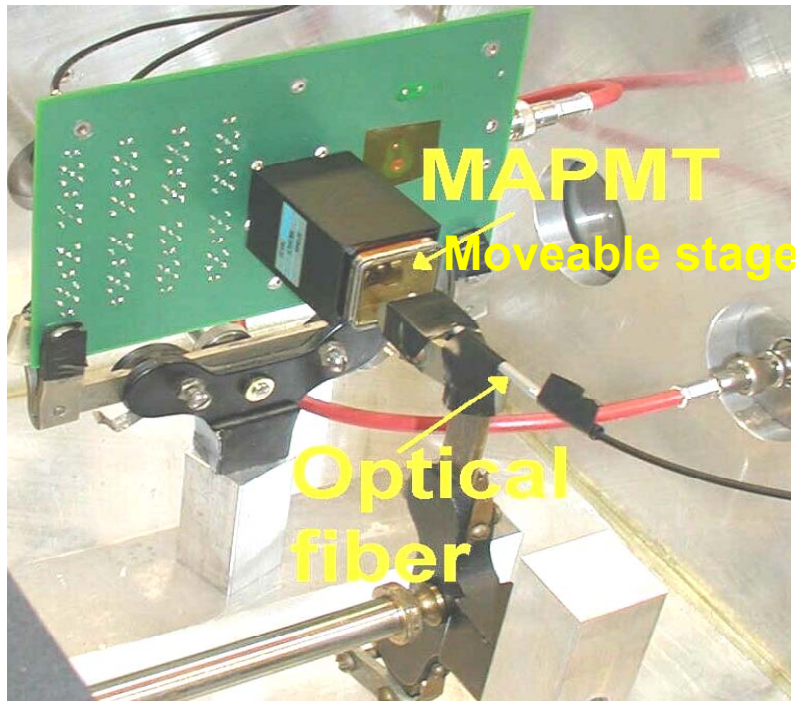
MAPMT Performance Characterization

We have acquired 2+ 52 MAPMTs: 2 Fully characterized & 52 recently purchased for upcoming test beam studies.

- Characterization steps:
  - Plateau
  - Active area
  - Gain and collection efficiency (CE) variation over the tube area

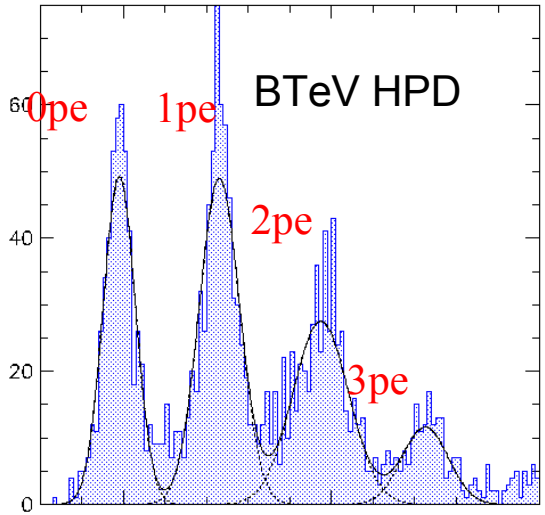


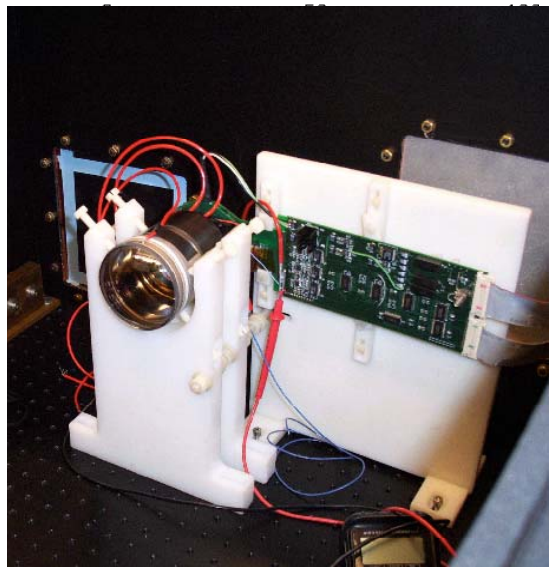
PULSE HEIGHT DISTRIBUTIONS FOR THE 16 CHANNELS OF R8900-M16 PROTOTYPE



BTeV HPD

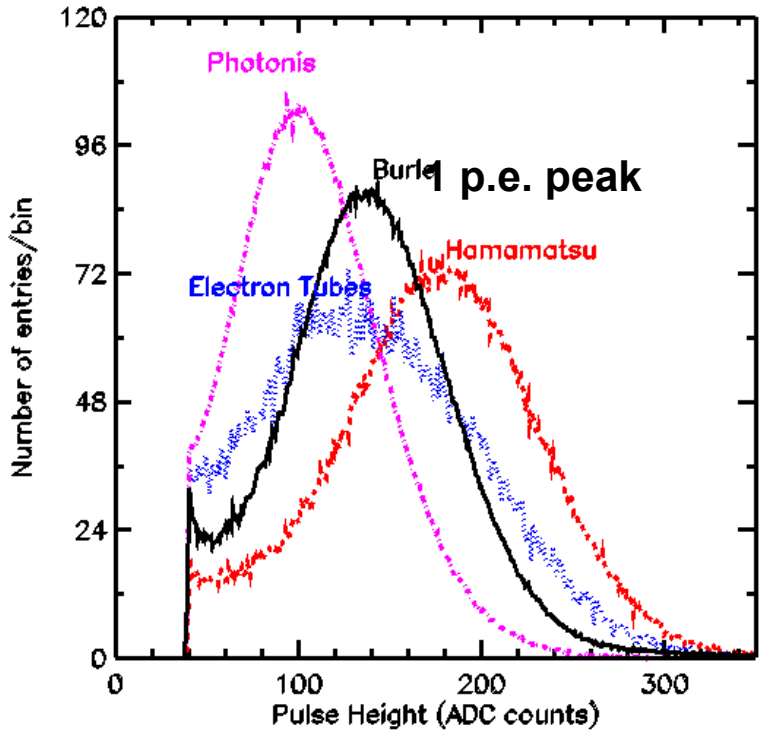
- 15 prototypes tested at Syracuse with LED light using CLEO III VA-RICH readout:
  - HPD works as expected
  - The development was a success!
- HPD being tested with VA_BTeV front end electronics
  - Seen response to single photoelectron
  - A system of 15 fully instrumented HPD's is being assembeld and will be studied in a test beam at FNAL in June 2004



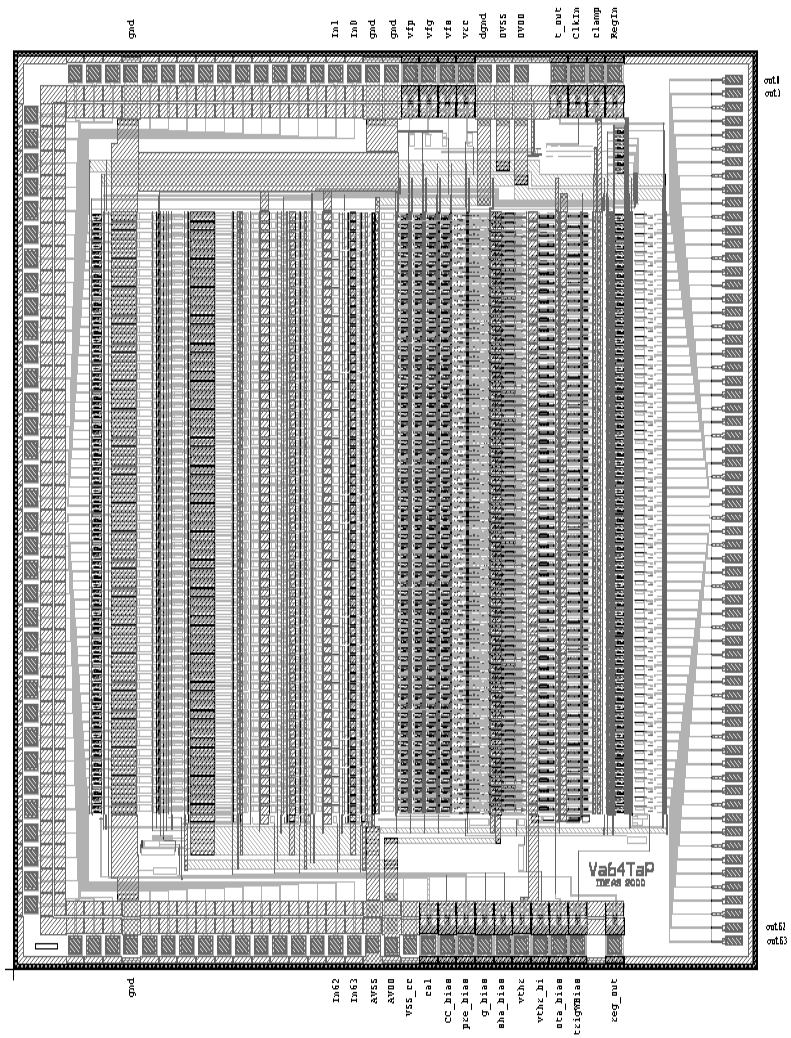


Photodetectors for the Liquid Radiator RICH

- Standard (single anode) 3" PMT:
  - Need about 5,000 tubes
  - 8-stage box dynode structure; gain ~10^5
  - Produced in mass quantities for medical applications
- We tested sample tubes from 4 manufacturers:
  - Burle, Electron Tubes, Photonics and Hamamatsu
  - All capable of detecting a single photon
  - Magnetic field sensitivity was determined (OK when shielded by mumetal tubes)



Photon detector electronics

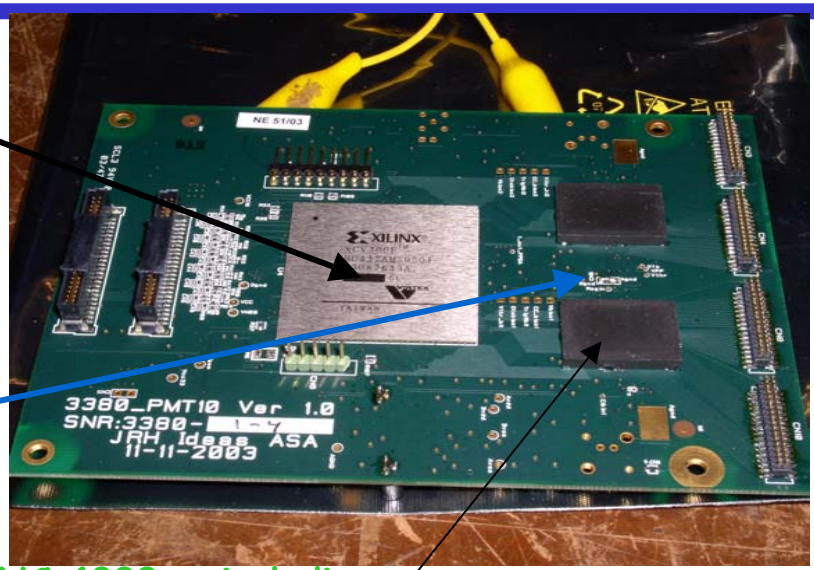


- FRONT END ASIC must
  - Low noise (~1000 e⁻)
  - On chip sparsification
  - High Dynamic range
  - Parallel digital readout to allow event synchronization
- PROTOTYPING STEPS implemented:
  - VA_BTeV1 [for HPD readout: low noise (500e⁻ ENC), discriminator not optimized for high counting rates]
  - VA_MaPMT [for MAPMT, improved discriminator, 1 analog test channel]
  - Va+BTeV1.1 [improved discriminator and 1 analog test channel]

Front End hybrids

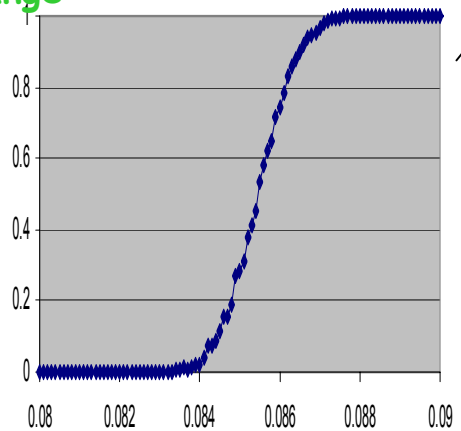
FPGA for data flow control

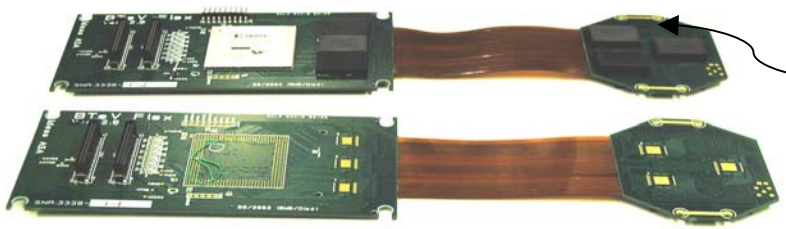
2 ASICs under light shield-caps

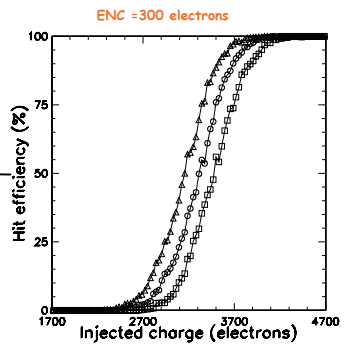


- 2 ASIC [128 channels] hybrids designed to process the information of 8 MaPMTs.
- Test bench characterization of 15 hybrids produced for the test beam shows that they match our requirements.
- Alternative solution for HPD engineered and tested.

measured ENC 4000 e^- including coherent noise, high dynamic range



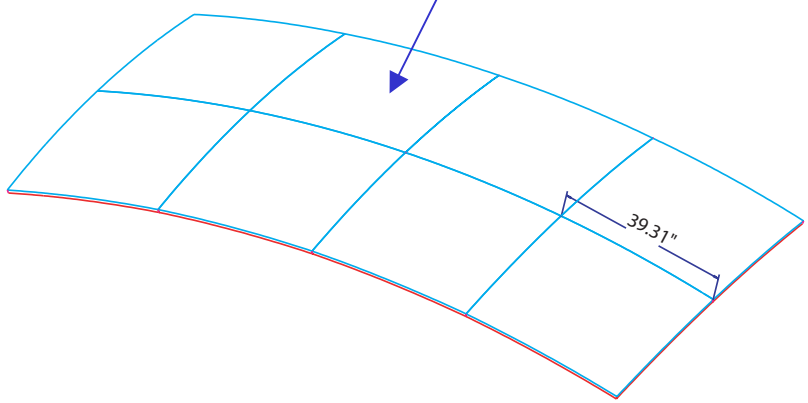




The RICH Mirror System

- Two large mirrors, each one has 200cm (width) and 400cm (height). They can be broken down to any number of mirrors of any shape, so that cost and performance are optimized.
- A half circle hole in the side (of radius ~3 cm).
- Mean radius is fixed to 697cm.
- 1-2% radiation length
- CMA approach: each mirror made up of 8 square tiles

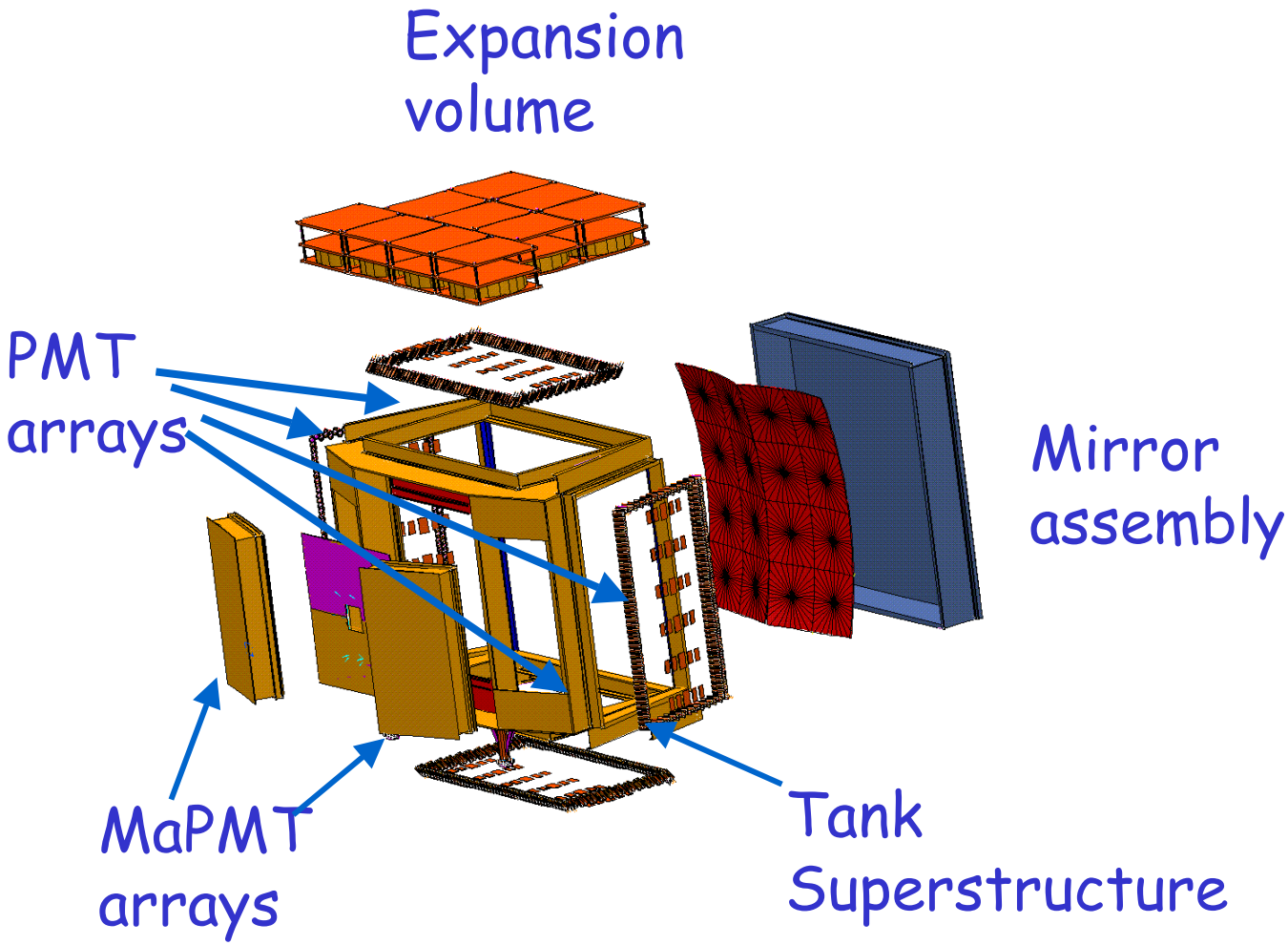
½ of RICH mirror based on CMA segment design



Example of CMA PROJECTS

•CMA provided competitive quote & demonstrated capabilities beyond our needs (optical properties controlled to fraction of a wave)

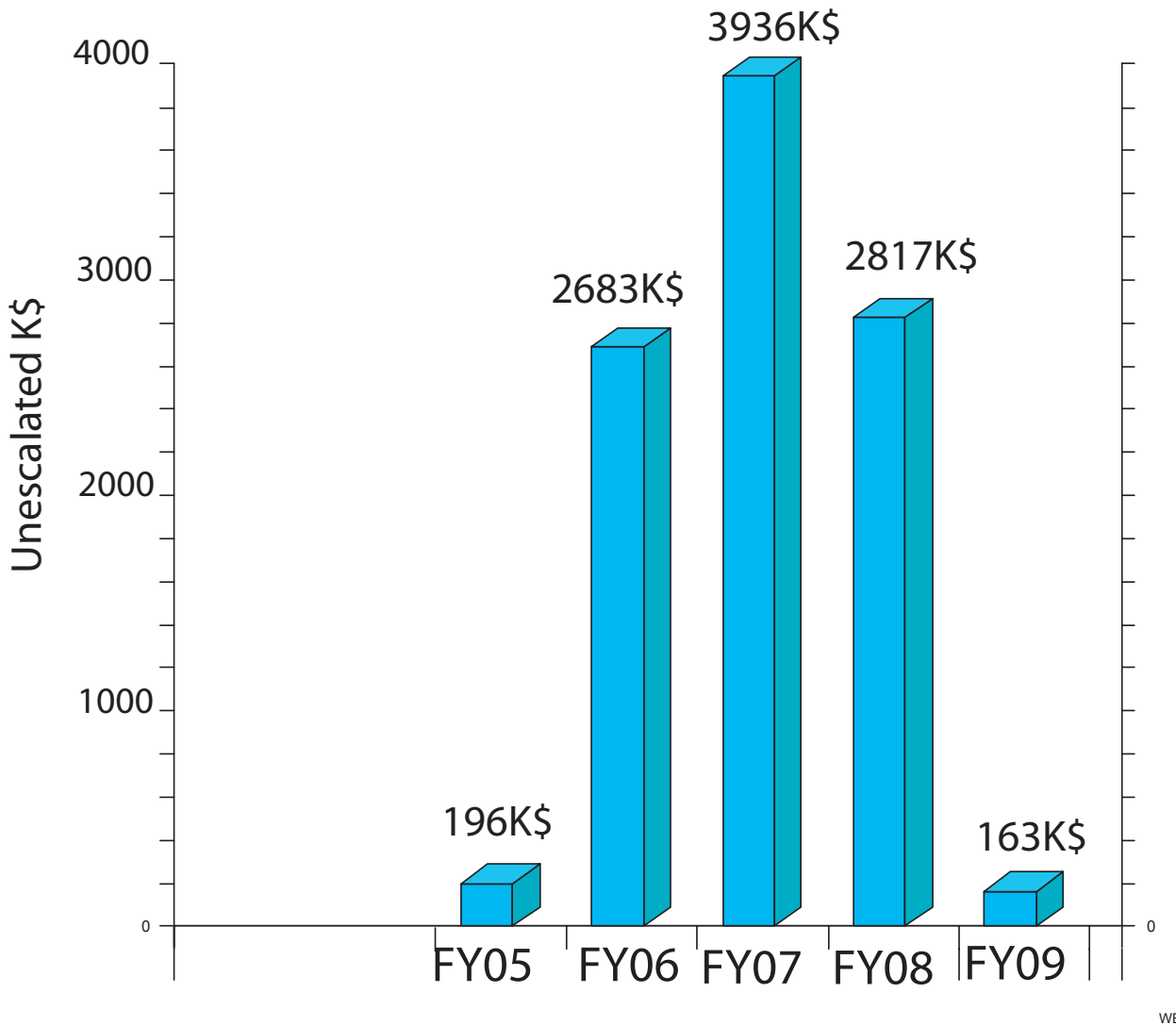
The RICH Vessel Superstructure



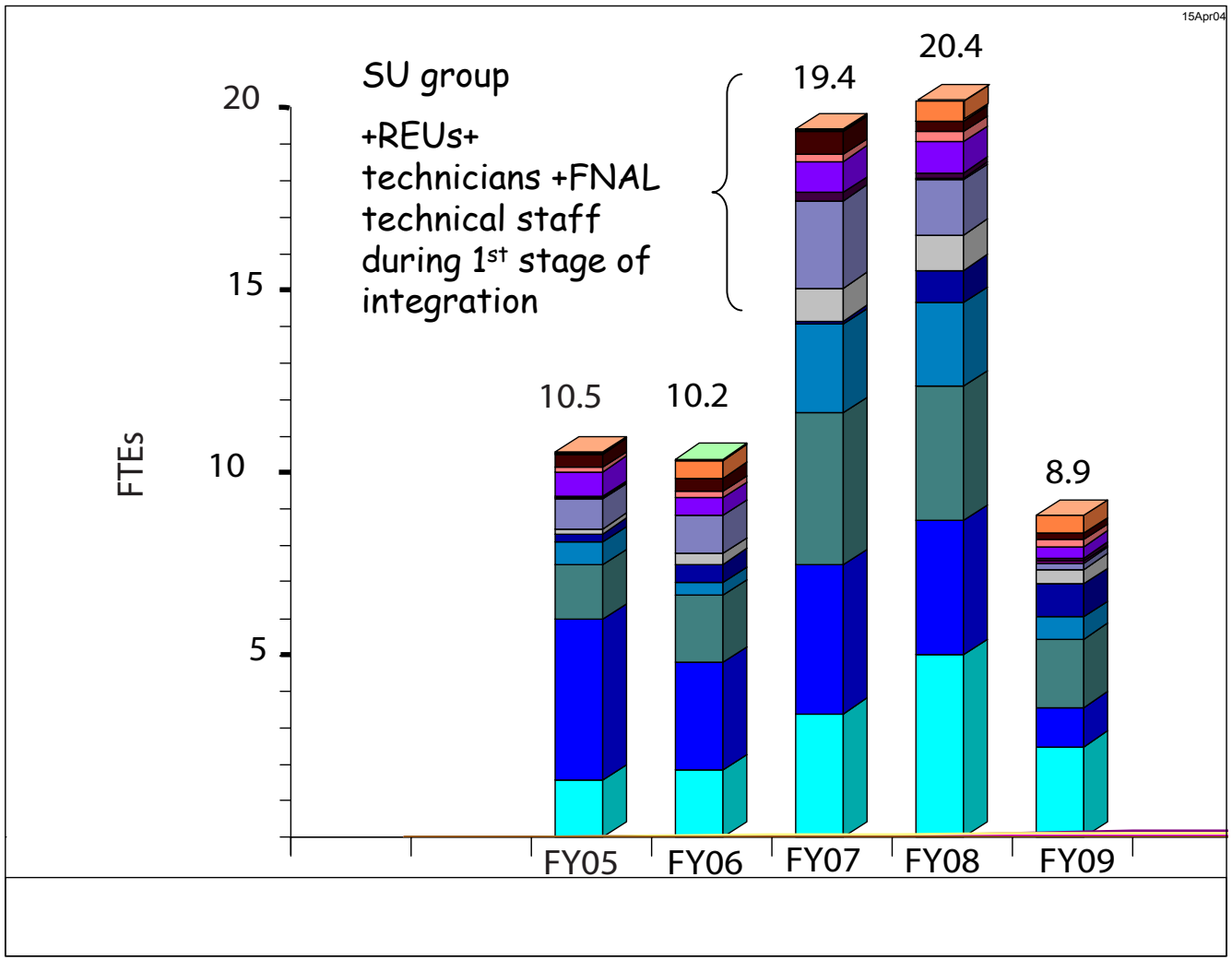
Construction Cost WBS 1.3

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.3.1	Multi-anode PMT Photon Detectors (MAPMTs)	5,339,792	40	32	0	2,124,674	3,404,812	1,850,772	66,083	7,446,340
1.3.2	Photomultiplier Tubes (PMTs)	1,082,531	25	25	0	747,859	575,670	31,565	0	1,355,095
1.3.3	Photon Detector Electronics	1,710,105	47	43	151,797	191,278	1,121,270	1,027,554	19,114	2,511,013
1.3.4	Mirror Arrays	804,286	53	34	0	893,307	214,146	86,365	0	1,193,818
1.3.5	Mech Gas Liquid & Related Systs	1,483,679	28	28	216,547	63,293	987,020	522,916	112,234	1,902,011
1.3.6	Power Monit Cooling & Related Systs	784,049	25	20	10,545	0	60,308	768,837	132,767	972,457
1.3.7	RICH Detector Install & Integ & Test	385,966	21	29	159,395	34,604	69,929	151,761	78,205	493,895
1.3.8	RICH Detector SW	198,110	46	33	0	0	56,275	107,462	104,469	268,206
1.3.9	RICH Detector Subproj Mgmt	272,452	20	20	88,690	98,362	61,186	36,930	41,775	326,943
1.3	**Subproject 1.3**	**12,060,969**	**38**	**29**	**626,974**	**4,153,377**	**6,550,615**	**4,584,165**	**554,647**	**16,469,779**

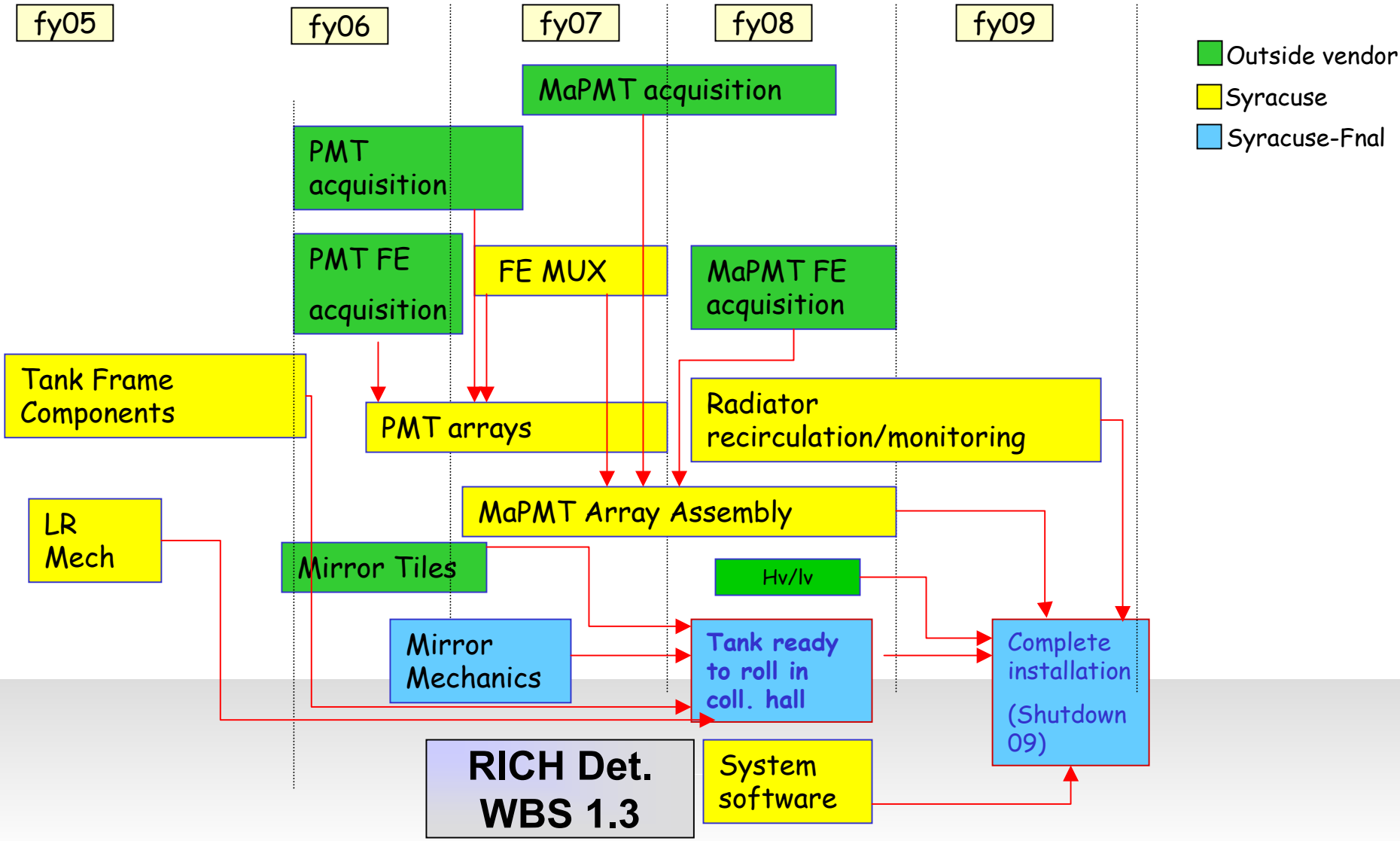
M&S Obligation Profile by Fiscal Year WBS 1.3



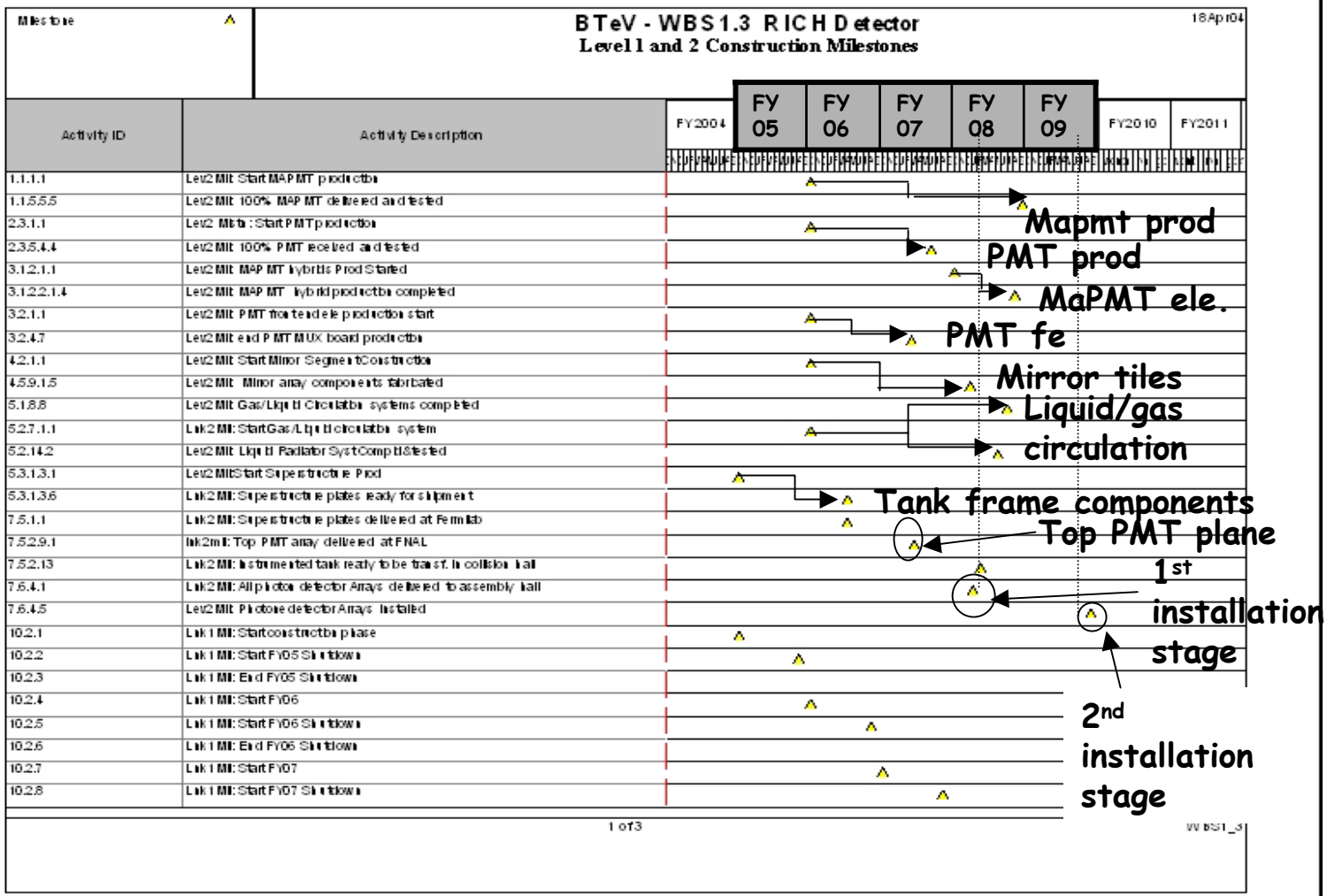
Labor Profile by Fiscal Year WBS 1.3



Description of project flow WBS 1.3



Key Milestones WBS 1.3



Critical Path Analysis WBS 1.3

BTeV - WBS 1.3 RICH Detector
Barchart for Critical Path Analysis
Sorted by Float

Planned
Critical
Late Dates
Milestone
Progress
Summary
Float

Activity ID	Activity Description	Activity Type	Duration	Float	Early Start
1.4.1	Finalize Mount& calibration scheme Des	ASAP	15d	64d	01Oct08
1.4.2	Acq parts for Mount& calibration Syst Prod	ASAP	60d	64d	22Oct08
1.4.3	Fab parts for Mount& calibration Syst Prod	ASAP	60d	64d	22Oct08
1.4.4	Construct Mount& calibration Syst	ASAP	40d	64d	23Jan09
1.4.5	Characterize Perfance of Mount& calibration Syst	ASAP	20d	64d	20Mar09
3.1.2.1.1	Lev2Mil: MAPMT hybrids Prod Started	Start Milestone	0	78d	01Oct07
3.1.2.1.2	Visit the MAPMT electronics manufacturer (IDEAS)	ASAP	10d	78d	01Oct07
3.1.2.1.3	Write Tech Specs Doc for MAPMT hybrids	ASAP	3d	78d	01Oct07
3.1.2.1.4	Write Prod Contract Doc for MAPMT hybrid Prod	ASAP	2d	78d	04Oct07
3.1.2.1.5	Negotiate Final Contract w/MAPMT hybrid manufacturer	ASAP	5d	78d	08Oct07
3.1.2.1.7	Ship this batch of VA_BTEV hybrids & clear customs	ASAP	10d	78d	12Mar08
3.1.2.2.1.1	monitor Fab process& get ready to receive shipment	ASAP	90d	78d	26Mar08
3.1.2.2.1.2	Fab this batch of VA_BTEV hybrids	ASAP	90d	78d	26Mar08
3.1.2.2.1.3	Ship this batch of VA_BTEV hybrids & clear customs	ASAP	5d	78d	01Aug08
3.1.2.2.1.4	Lev2Mil: MAPMT hybrid production completed	Finish Milestone	0	78d	07Aug08
3.1.2.3.2.1	Rev Veriel characterization	ASAP	1d	78d	08Aug08
3.1.2.3.2.2	test hybrids	ASAP	100d	78d	11Aug08
3.1.2.4.2.1	Mount MAPMT hybrids in long term test station	ASAP	50d	78d	07Jan09
3.1.2.4.2.2	Monitor hybrids in long term test station	ASAP	40d	78d	07Jan09
3.1.2.4.2.3	test Perfance upon burn-in completion	ASAP	45d	78d	05Mar09
3.1.2.4.2.4	Store batch of VA_BTEV hybrids at SU (long term)	ASAP	2d	78d	07May09
3.1.2.4.2.5	Lev2Mil: 100% MAPMT hybrids certified	Finish Milestone	0	78d	08May09
5.1.4.1.1	Des radiator gas circulation Syst	ASAP	80d	16d	27Feb08
5.1.4.1.2	Acq Mat'l for gas circulation Syst	ASAP	100d	16d	19Jun08
5.1.4.1.3	Fab parts for gas circulation Syst	ASAP	120d	16d	19Jun08
5.1.4.1.4	assemble gas circulation Syst	ASAP	60d	16d	10Dec08
5.1.4.1.5	assess Perfance of Proto gas circulation Syst	ASAP	80d	16d	11Mar09
5.1.4.1.7	Lev3Mil: gas circulation Syst Compld&certified	Finish Milestone	0	16d	09Jul09
5.2.2.1	order liquid needed	ASAP	1d	63d	01Oct08
5.2.2.2	Acq liquid needed	ASAP	60d	63d	02Oct08
5.2.2.3	Lev3Mil: Received Del of radiator liquid	Finish Milestone	0	63d	30Dec08

FY04 FY05 FY06 FY07 FY08 FY09 FY

Last step of calibration and monitoring infrastructure

Electronics acquisition delayed (well established component)

Gas circulation system assembled during last stages of detector integration

- Risks
  - MaPMT acquisition: Escalation of cost due to single vendor
  - Vendor fails to deliver low mass mirrors satisfying all of our requirements within the time and budget agreed upon.
- Mitigation
  - Fully developed HPD system provides viable alternative
  - Work with multiple vendors + multiple technologies (glass, Be substrates)

Summary

- Dual radiator RICH (mirror focused gas radiator + proximity focused liquid radiator) will provide excellent hadron identification and enhance lepton identification
- Prototypes for all the subsystems developed and studied in test stands at Syracuse and a test beam run at Fermilab is planned this Summer.
- Cost in check via multiple vendors/technologies
- Experienced team that has already built a large RICH system (CLEO RICH, operating extremely well since 1999 at CESR e^+e^- collider)
- More information on the RICH Detector System (WBS 1.3) will be provided in the breakout session
  - Project Overview – Marina Artuso
  - Photon detectors – Tomasz Skwarnicki
  - Front end electronics – Marina Artuso
  - Mirror design – Tomasz Skwarnicki
  - Mechanical design and installation plans – Herman Cease

Glossary of Terms

- MAPMT module: 32 MAPMT units mounted on a HV base board [HV connector + voltage dividers]
- MAPMT channel: support structure for 1 row of 49x4 MAPMTs
- PMT module: single PMT in injection mold ready for assembly in PMT beehive
- PMT beehive: PMT array support structure and B-field shield made up of mu-metal cylinders glued together
- FE electronics: Front End Hybrids [mixed-analog-digital front end circuitry] + Front end MUX [x4 multiplexer boards connected with remote data combiner boards]